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Acquisition Risks in a World of Joint Capabilities

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Abstract

This study reports some preliminary results of a research agenda that seeks to address the absence of tested metrics to provide early indication of the acquisition risks of interdependent programs. The overall goal of this research is to forge new ground on uncovering early indicators of interdependency acquisition risk, so appropriate governance mechanisms can then be isolated. Funding will allow the ability to 1) expand on an existing database of Major Defense Acquisition Program (MDAPs) performance data, 2) analyze the MDAPs to characterize the risks attributable to interdependence, and 3) determine whether acquisition setbacks cascade to downstream interdependent MDAP programs. The deliverables of the effort are 1) a code book of DoD data acquisition items that can be employed in future research efforts, and 2) the results of the investigation of the cascading risks of interdependent acquisition efforts.

In short, preliminary results indicate that perceptions of risk may prove influential on downstream program performance. In terms of the direct influence that an upstream program's performance might exert on downstream program performance, weak, but statistically significant, relationships were noted in three areas. The next steps of the research are to 1) expand the dataset to include FY 2009 data, 2) document acquisition data, 3) collect a number of indicators on program interdependency, and 4) test a number of interdependency diversity metrics in terms of their ability to provide insights on program performance.

Introduction

This research effort addresses two critical problems: 1) Data on major defense acquisition programs is piecemeal and fragmented, thus hindering acquisition research; 2) There is an absence of tested metrics to provide early indication of the acquisition risks of interdependent programs.

A wealth of research indicates that the use of programmatic networks in the public sector is clearly on the rise (Weber & Khademian, 2008). Noting that firms do not act by themselves, Granovetter (1973) witnessed that organizations are deeply embedded in "networks of external relationships" that influence the exchange of resources and capabilities among them. Increasingly, state-, local-, and federal-level agencies are turning to joint interdependent programs to address gaps that only cross collaborative initiatives can span. Yet, as discussed below, the study of interdependency and its effects on program performance have yielded too few tangible results. For purposes of the discussion below, jointness, interdependency, exchange, and partnerships, all refer to a similar concept: the notion that autonomous organizations build relationships to provide capabilities that, when looked at in totality, form network structures. Additionally, at the individual pair-wise level, the exchanges are manifested as explicit transactions.

Scholars have long contended that many contemporary policy challenges, and their associated solutions, lie across organizational domains outside the jurisdiction of any one agency (Gage & Mandell, 1990; Alexander, 1995; Agranoff, 2003). Milward and Provan (2001) show that public policy arenas are inherently crosscutting; the requisite knowledge and corresponding solutions are not localized, but are instead distributed across a range of agencies and organizations. The DoD's transformation to joint capabilities is in keeping with the ongoing trends. Historically, acquisition investments at the DoD had been proposed as individual materiel solutions, typically championed by the armed service for which the product was to be obtained. This gave rise to discrete systems designed in accordance with the individual service requirements. When called upon to operate in a joint, multi-service environment, these systems exhibited problems interacting effectively with other service systems.

The Transformation to Joint Capabilities attempts to provide military forces with the capability to adapt quickly to new challenges and unexpected circumstances by leveraging a wider range of assets. Central to the Transformation was the desire for enhanced coordination among agencies and across all levels of government (coalition, federal, state, and local). In addressing the need for interagency cooperation, Vice Chairman of the Joint Chiefs of Staff Admiral Giambastiani (2004) claimed that the integrated force had to become interdependent. That is, it must be capabilities-based, collaborative, and network centric. Military efforts require the ability to conduct high-level, or large-scale, vertical and horizontal collaboration. That means up and down the chain of command and across all capabilities and forces.

While DoD agencies are expected to embrace joint capabilities, literature findings regarding the risks and best practice mechanisms of joint interdependent activities lag far behind. Whereas early research did provide some insights, the research activities have stalled and progress is lacking. For example, back in 1937, Coase found that interdependencies are based on mutual exchanges that can be examined at the transaction level. He argued that these transactions accrued costs that could be attributed to establishing the rules of engagement, enforcing agreements, and monitoring compliance. Unfortunately, specific cost functions were never isolated.

In 1967, Thompson contributed to the research by offering a tripartite model that focused on the configurations of the transaction flows. Sequential flows involved handoffs between partners. Pooled flows involved partners that drew down from a common source of assets and the flows of reciprocal relationships involved feedback mechanisms. Much of the research to date has been based on the anecdotal findings of small *n* case studies (Isett & Provan, 2005; Meier & O'Toole, 2008). While the three configurations provide a starting point for understanding interdependent activities, the reality of today's activities are far more complex. In short, it is not unusual for the acquisition or production of a service to incorporate multiple configurations with resources flowing in and out across organizations of public and private entities. As such, the most common configuration is the "mixed" pattern incorporating all three of the configurations and a wide array of nodes, assets, channels and zones.

Exchange theorists argue that organizations develop interdependent relationships with other organizational entities to either obtain critical resources or provide critical capabilities. They also assert that interdependent relationships exhibit high levels of uncertainty due to participant constraints (Miles & Snow, 1978). Shirking or defection of a network member can have dire consequences on the survival and performance of the network in total and network participants in general. Because of the nature and influence of the ties or interdependencies that bind organizations, Levinthal's (1997) research indicated that increasing the density of the interdependencies that connect the organizations affects the complexity of the "landscape" in which it operates. Levinthal (1997) finds that these interconnections or flows can yield nonlinear consequences that often involve multiplier effects based on the nature of the interdependencies in the system. Apparently, the value chain of the joint capabilities is laden with junctions and bifurcations where delay, defection, or shirking can occur. In fact, in 1999, Rosen argued that the uncertainty that arises from a relationship is the definition of "complexity." And that "complexity" can only be understood by examining the links that bind. If Rosen is correct, then DoD acquisition is reaching unprecedented complexity. A network analysis of MDAP data interdependencies suggests overwhelming complexity (see Figure 1). The 78 MDAPs in 2005 demonstrated 989 unique links to other MDAPs as well as non-MDAP programs. The yellow links indicate medium risk relationships and the red links show high risk links.

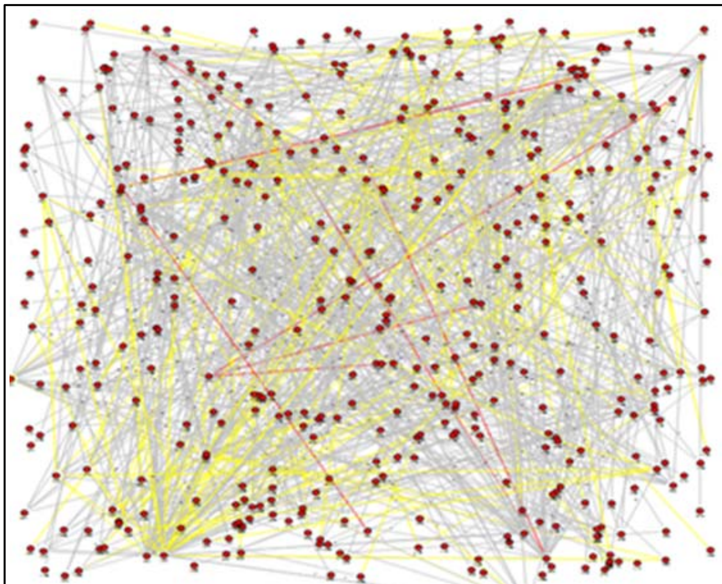

Figure 1: MDAP Data Interdependencies in 2005

Despite the activities, ten years ago Agranoff and McGuire (2001) wrote that "there are many more questions than answers in network management" and the assertion continues to ring true. Apparently, the field is rich in anecdotal findings but poor in empirical evidence (Alexander, 1995). Oliver and Ebers (1998) liken the state of the field as a messy situation marked by a cacophony of heterogeneous concepts, theories, and research

results. While the growth is clearly on the rise, DoD acquisition is moving forward with little insights into the risks and threats of joint efforts. Without a deep understanding of the risks and threats that interdependent efforts encounter, governance mechanisms that can help to insure acquisition success are beyond reach. Given the pace at which joint efforts are pursued, early indicators of acquisition risk are needed to help isolate the critical governance mechanisms that will mitigate performance shortfalls.

Additionally, of utmost concern is the state of current acquisition data. While several initiatives are underway to compile the sundry datasets the fragmented acquisition data puts decision-making at risk for Type I and Type II errors (false positive and false negative, respectively). Funding for this research effort will allow the ability to integrate, cleanse, and normalize authoritative datasets for the purpose of advanced research. It will also provide the ability to document the acquisition data for future research purposes. The documentation will allow the research community to forge new insights in the acquisition arena.

The study of DoD acquisition efforts for gaining insights on interdependency is especially fruitful. First, the DoD has rich, but fragmented and piecemeal, datasets on some of the important key interdependencies of major defense acquisition programs. Second, the movement toward joint capabilities makes an understanding of interdependencies especially critical. Finally, given the frequency with which government agencies are moving toward joint initiatives, findings based on DoD programs may prove instrumental to a wide range audience. The research below examines the ties that bind organizations in light of two different types of transactions: data ties and funding ties. And it begs the questions: do the ties result in cascading acquisition risks? The research will act as a catalyst for a long-term research program on the risks and governance mechanisms of joint acquisition initiatives.

Research Objectives: The objectives of the research are as follows:

1. To map program interdependence to reveal the directionality of influence (i.e., “upstream”/“downstream”) of cause-effect relationships,
2. To test the cascading risks that upstream programs exert on downstream programs in light of data and funding exchanges,
3. To test the extent to which the cost overruns of upstream programs cascade on to interdependent downstream programs,
4. To test the extent to which schedule delays cascade on to interdependent downstream programs,
5. To use the findings to make recommendations on potential governance mechanisms that may prove capable of mitigating the risks of interdependencies, and
6. To provide a research code book of acquisition data elements for future research efforts.

The remaining discussion provides an interim report on some of the findings to date, based on the interdependent activities identified in the Defense Acquisition Executive Reviews (DAES). The findings below examine the influence of interdependencies on a number of program performance measures.

Research Methods: Because of data availability issues, the unit of analysis for this research was restricted to Major Defense Acquisition Programs (MDAPs). Starting in the 2005 time period, Major Defense Acquisition Program managers were asked to provide reports on what they considered to be the critical interdependencies of their given program. They identified upstream and downstream connections and indicated the perceived risk level (red, yellow, green). Because of a small number of red risks, the risk variable was recoded to reflect "no-risk," "risky." Hence the "risk" variable is binomial in nature. The research findings described below are based on the influences these interdependencies might exert on program performance.

Program performance is considered from multiple vantage points. Table 1 provides all the variables used in this research and the documents they were derived from. In short, performance is based on 1) annual cost variance figures (for total cost variance and the subsets of schedule, estimation, and engineering cost variance in millions), 2) DAES breaches (schedule, performance, and Research, Development, Testing, and Evaluation (RDT&E) breaches), and 3) percent cost growth from the original RDT&E estimates. All variables were derived from Selected Annual Reports (SARs) and DAES reports. Because 2005 marked the first year that the DAES reports began reporting interdependencies, the analysis reported below is based on MDAP performance in fiscal years 2005, 2006, and 2007 (note: SAR reports were not reported in FY2008 due to the new presidential administration).

Table 1. Variables Used in the Research

Unit of Analysis: Major Defense Acquisition Programs	
Variable	Data Source
Count of APB Schedule Breaches Count of APB Performance Breaches Count of APB RDT&E Breaches Count of APB PAUC Breaches	DAES
Total Cost Variance Engineering Cost Variance Schedule Cost Variance Estimation Cost Variance	SAR
Percent Cost Growth	SAR
Data Exchange Interdependencies	DAES Interdependency Charts

As identified above, MDAP program managers were asked to provide insight on what they perceived to be the program's interdependencies. They also reported on the direction of the interdependency (inbound, outbound, and bidirectional) and the risk of the interdependency. The risk is based on the sender's perceived risk with a downstream receiver. Because performance data on non-MDAP programs were not available for analysis, the findings considered only the interdependencies that existed among MDAPs.

Findings: Two major sets of findings are discussed below. The first is based on the influence of the sender's perceived risk with the downstream receiver's performance (during years 2005-2007). The sender's "perception of risk" is also considered in light of their own

individual performance (during years 2005-2007). To measure the sender's perceived risk on their individual performance, the mean of the risk of all the relationships was calculated to provide an overall "risk" level for each MDAP. The second set of findings is based on the sender's performance and its influence on the receiver's performance. Table 2 provides the means and standard deviations of all variables used in the research. The number of downstream programs per upstream MDAP ranged from 1 to 23, with a mean of 5. A total of 873 relationships were analyzed over the three-year time period.

Table 2. Descriptive Statistics of Variables Employed in the Research

	N	Mean	Std. Deviation
Upstream APB Schedule Breaches	269	.36	.481
Upstream APB RDT&E Breaches	522	.09	.289
Upstream APB PAUC Breaches	522	.08	.266
Upstream APB Performance Breaches	522	.13	.333
Downstream APB Schedule Breaches	518	.27	.444
Downstream APB Performance Breaches	522	.06	.240
Downstream APB RDT&E Breaches	522	.11	.319
Downstream APB PAUC Breaches	522	.11	.312
Upstream Perceived Risk	522	1.1073	.30977
	N	Mean	Std. Deviation
Upstream Percent Cost Growth	840	.08	1.00
Upstream Engineering Cost Variance	711	5.53	91.06
Upstream Schedule Cost Variance	711	4.76	38.31
Upstream Estimation Cost Variance	711	.32	159.33
Upstream Total Cost Variance	840	4.75	208.20
Downstream Percent Cost Growth	446	.014	.10
Downstream Engineering Cost Variance	351	-6.12	219.25
Downstream Schedule Cost Variance	351	3.77	25.05
Downstream Estimation Cost Variance	351	-7.95	324.36
Downstream Total Cost Variance	449	-38.79	400.26

Interdependency Risk. The first set of tests sought to determine if the sender's perceived risk of the relationship influenced its partnering receiver. In terms of the "partner risk" variable, xx% of the MDAP program managers identified no risk in the partnerships. Xx% indicated some degree of risk in the relationships. Of the 56 programs that indicated some risk, the risk ranged from a low of 1.1 to a high of 2 (recall that the variable ranges from "1" to "2," with "1" indicating no risk). Correlation coefficients were then obtained (see Table 3). The data show that the Manager's Perception of Risk is *negatively* with the partner's total cost variance, engineering cost variance, and estimation cost variance.

Interestingly, risk was correlated with the downstream partner's performance, RDT&E, and PAUC breaches, but in a *positive* direction. The fact that an upstream partner's perception of risk might result in an *increase* in the number of DAES' breaches illustrates the detrimental influence that upstream programs might exert on their downstream partners. But, why the *negative* relationship with cost variance? Why would an increasing perception of risk on the upstream program result in reducing the cost variance of its downstream partners? Perhaps the answer lies in the old adage that perceptions of risk result in increased attention. Perhaps, under high-risk situations, program managers are more cognizant of the risk and act to mitigate the detrimental effects. More research is clearly warranted to tease out why these correlations are demonstrated.

Table 3. Bivariate Correlation with MDAP Program Manager's Perception of Risk

MDAP's Percent Cost Growth	-.024
MDAP's Total Cost Variance	.019
MDAP's Engineering Cost Variance	-.081*
MDAP's Schedule Cost Variance	-.007
MDAP's Estimation Cost Variance	.05
MDAP's Schedule Breaches	.05
MDAP's Performance Breaches	.11*
MDAP's RDT&E Breaches	.13**
MDAP's PAUC Breaches	-.05
Downstream MDAP's Percent Cost Growth	-.07
Downstream MDAP's Total Cost Variance	-.12**
Downstream MDAP's Engineering Cost Variance	-.22**
Downstream MDAP's Schedule Cost Variance	-.05
Downstream MDAP's Estimation Cost Variance	-.11*
Downstream MDAP's Schedule Breaches	.07
Downstream MDAP's Performance Breaches	.13**
Downstream MDAP's RDT&E Breaches	.09*
Downstream MDAP's PAUC Breaches	.12**
* p < .05 ** p < .00	

The next step of the "risk" analysis sought to isolate whether the MDAP's mean risk score influenced their own specific performance. The results show that the manager's perception of risk is positively correlated with the program's engineering cost variance. Outside of engineering cost variance, despite recognition of risk, no notable correlations were demonstrated in terms of DAES breaches, cost variance, or cost growth.

The second set of tests sought to identify whether the performance of upstream programs exert influence on their downstream partner's performance. Because an upstream program's influence would not expect to have an immediate effect, the data were lagged a year. In other words, one might expect that the negative effects of an upstream program would influence their downstream partners one year out. Table 4 shows the results

of the sender's performance on the downstream partners. The results show little influence on APB breaches. A weak, but statistically significant, relationship was demonstrated between the number of upstream program RDT&E breaches and the number of downstream program RDT&E breaches. In terms of the influence of the upstream program's percent growth, it showed no correlation with the downstream program's percent growth. Two of the cost variance relationships also showed weak, but statistically significant, correlations. The sender's total cost variance appeared to exert some influence on the downstream program's schedule variance. In addition, as the sender's engineering cost variance rose, a subsequent rise was also noted in the downstream program's percent cost growth.

Table 4. The Influence of the Sender's Performance on Downstream Programs FY 2005-2007 (Lag of One Year)

		SENDER MDAP								
		APB Schedule Breaches	APB RDT&E Breaches	APB Performance Breaches	APB PAUC Breaches	Total Cost Variance	Engineering Cost Variance	Schedule Cost Variance	Estimation Cost Variance	Percent Cost Growth
DOWNSTREAM MDAP	APB Schedule	-.03	.04	-.01	.05					
	APB RDT&E	-.00	.07*	.02	-.05					
	APB Performance	.06	.04	-.00	.01					
	APB PAUC	-.03	.05	-.02	.00					
	Total Cost Variance					-.02	.09	-.06	.01	-.01
	Engineering Cost Variance					.02	.09	-.06	.02	-.01
	Schedule Cost Variance					.09*	-.04	.05	-.02	-.00
	Estimation Cost Variance					-.08	.09	.02	.03	.02
	Percent Cost Growth					-.02	.12**	-.00	.02	-.00

Conclusions

The results discussed above are the preliminary interim results of a segment of research that seeks to identify the influences that interdependencies might exert on acquisition program performance. In short, the results indicate that perceptions of risk may prove influential on downstream program performance. In terms of the direct influence that an upstream program's performance might exert on downstream program performance, weak, but statistically significant, relationships were noted in three areas. In subsequent months, we will complete the data collection effort and construct and test a series of interdependency metrics on program performance. The data will be modeled using traditional statistical approaches to assess causality. Additionally, we will employ Markov Decision Process (MDP)-based methods (Puterman, 1994) to take into account the cost and schedule variance specifications from the n-ordered downstream programs and produce a

specification of the best possible budget trimming options for the decision-maker. Formally, a MDP is a probabilistic model of a sequential decision problem, in which states can be perceived exactly, and the current state and action selected determine a probability distribution on future states (Bertsekas, 1987). Specifically, the outcome of applying an action to a state depends only on the current action and state (and not on preceding actions or states). We assume that state changes in our model occur only at discrete instances of time, allowing us to model the network as a discrete event dynamic system (DEDS) and plan to employ MDPs. Our model facilitates the data acquisition process since we iteratively refine the state features critical to the decision-making. The action space will capture information about the funders, including changes in level of funding. We plan to model the probability of transitions from one state to another empirically by using existing data. The "Reward" function will be the presence of a schedule delay and cost variance that occurs in n-ordered downstream programs. Hence, we will be assessing various interdependency metrics in light of statistical and MDP methods to isolate the most feasible method for understanding interdependencies.

In short, the next steps of the research are to 1) expand the dataset to include FY 2009 data, 2) document existing acquisition data sources, 3) collect a number of indicators on program interdependency, and 4) test a number of interdependency diversity metrics in terms of their ability to provide insights on program performance.

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- Individual Augmentation
- Learning Management Systems
- Moral Conduct Waivers and First-tem Attrition
- Retention
- The Navy's Selective Reenlistment Bonus (SRB) Management System
- Tuition Assistance

Logistics Management

- Analysis of LAV Depot Maintenance
- Army LOG MOD
- ASDS Product Support Analysis
- Cold-chain Logistics
- Contractors Supporting Military Operations
- Diffusion/Variability on Vendor Performance Evaluation
- Evolutionary Acquisition
- Lean Six Sigma to Reduce Costs and Improve Readiness
- Naval Aviation Maintenance and Process Improvement (2)
- Optimizing CIWS Lifecycle Support (LCS)
- Outsourcing the Pearl Harbor MK-48 Intermediate Maintenance Activity
- Pallet Management System
- PBL (4)
- Privatization-NOSL/NAWCI
- RFID (6)

- Risk Analysis for Performance-based Logistics
- R-TOC AEGIS Microwave Power Tubes
- Sense-and-Respond Logistics Network
- Strategic Sourcing

Program Management

- Building Collaborative Capacity
- Business Process Reengineering (BPR) for LCS Mission Module Acquisition
- Collaborative IT Tools Leveraging Competence
- Contractor vs. Organic Support
- Knowledge, Responsibilities and Decision Rights in MDAPs
- KVA Applied to AEGIS and SSDS
- Managing the Service Supply Chain
- Measuring Uncertainty in Earned Value
- Organizational Modeling and Simulation
- Public-Private Partnership
- Terminating Your Own Program
- Utilizing Collaborative and Three-dimensional Imaging Technology

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Acquisition Risks in a World of Joint Capabilities

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Joint Capabilities

Join Capabilities and Network Centric Warfare

is an emerging theory of war based on the concepts of nonlinearity, complexity, and chaos. It is less deterministic and more emergent; it has less focus on the physical than the behavioral;

and it has less focus on things than on relationships

ADM Cebrowski

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Complexity and Joint Capabilities

Nonlinear interaction	Combat forces composed of a large number of nonlinearly interacting parts
Decentralized Control	There is no master “oracle” dictating the actions of each and every combatant
Self-Organization	Local action, which often appears “chaotic,” induces long-range order
Non-equilibrium Order	Military conflicts, by their nature, proceed far from equilibrium. Correlation of local effects is key
Adaptation	Combat forces must continually adapt and coevolve in a changing environment
Collectivist Dynamics	There is a continual feedback between the behavior of combatants and the command structure

-- Moffat

Acquisition Reforms

Weapon Systems Acquisition Reform Act (WSARA) of 2009 Enacted as Public Law 111-23 on May 22, 2009

Implementing Management for Performance and Related Reforms to Obtain Value in Every Acquisition Act, or the IMPROVE Acquisition Act, by 417-3 on April 28.

Challenges with the requirements process are a major factor in poor acquisition outcomes

The requirements process for the acquisition of services is almost entirely ad hoc.

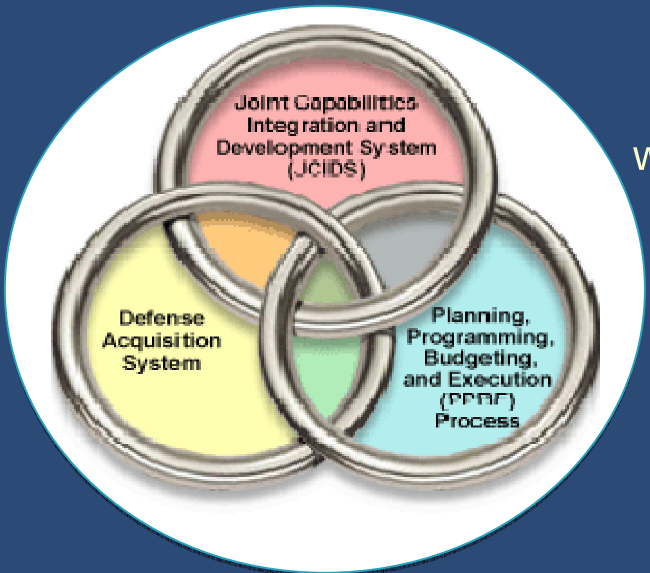
The process for developing requirements for the acquisition of weapon systems lacks the expertise and capacity required to vet joint military requirements.

Joint staff lacks some of the analytical expertise necessary to ensure that the JCIDS process rigorously vets proposed requirements

Joint Capabilities

An integrated approach to strategic planning, capabilities needs assessment, systems acquisition, and program and budget development.

To identify and assess joint military capability needs that serve as the basis for the development and production of acquisition programs



To assess and resolve gaps in military joint warfighting capabilities. To effectively integrate capabilities identification and acquisition provide capabilities-based approach to requirements generation

To provide joint analytic decision support with PPBE milestones

Because the future operating environment will be characterized by uncertainty, complexity, rapid change, and persistent conflict, DoD leadership has explicitly sought the capability to act jointly

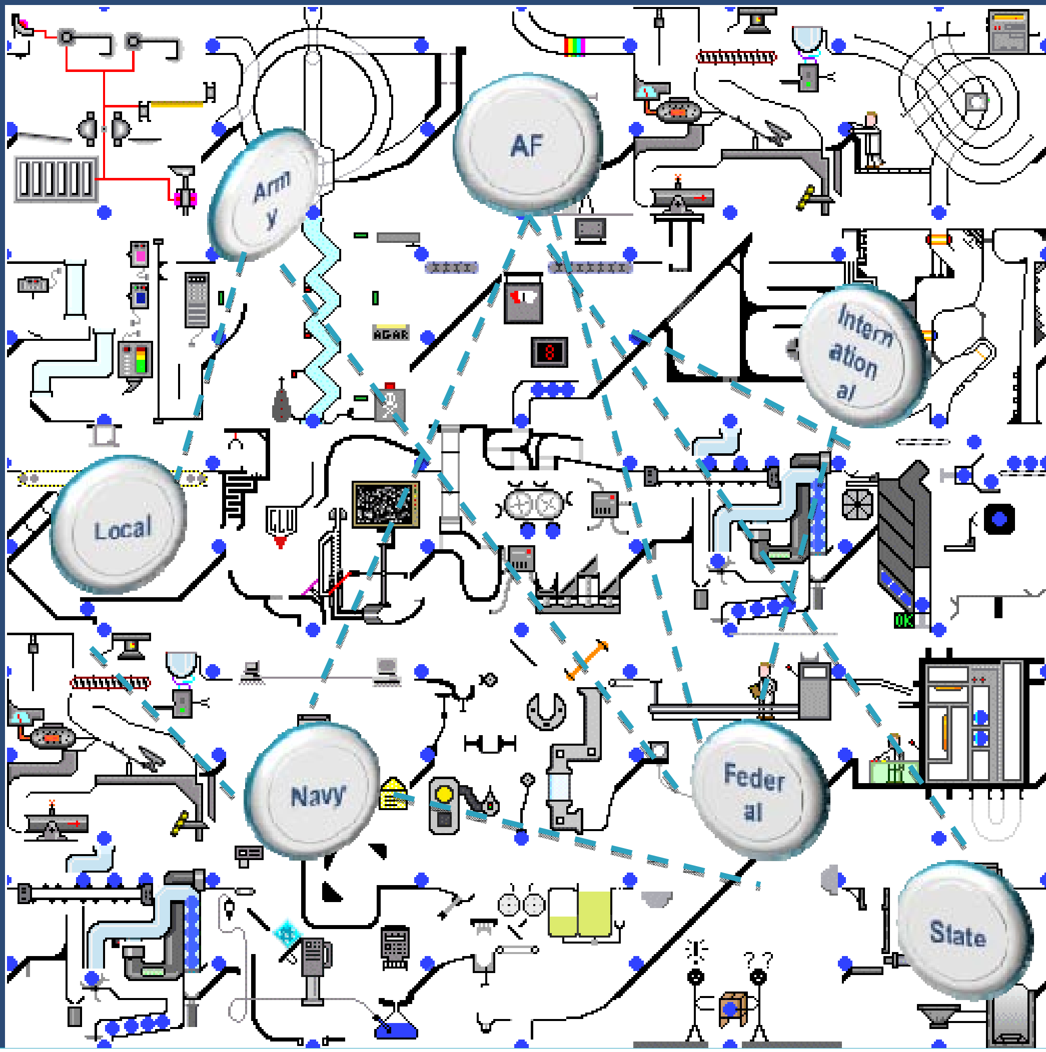
Interdependency :: Complexity

Complexity is based on

relations, and by

extension,

principles of organization



Research Goals

Are to identify the:

- Characteristics,
- Behavior, and
- Effects

of the Programmatic Networks that drive Joint Capabilities and Network Centric Activities

Vulnerabilities

- Incomplete Information
- Incomplete Payoff Structures
- Inability to Isolate Cause and Effect
- Unknown Response Options
- Multiple and Conflicting Representations of Environmental Variety
- Perturbations
- Multiple Constraints

- labor allocations
- production
- consumption
- investment decisions

Vulnerabilities

Bandwidth

Congestion

Noise

Stability

Redundancy

Transaction Costs

Reliability

Integrity

Performance

Cost Overruns

Schedule Delays

Feature Shortfalls

Interdependency Dimensions

Direction

Pooled
Sequential
Reciprocal

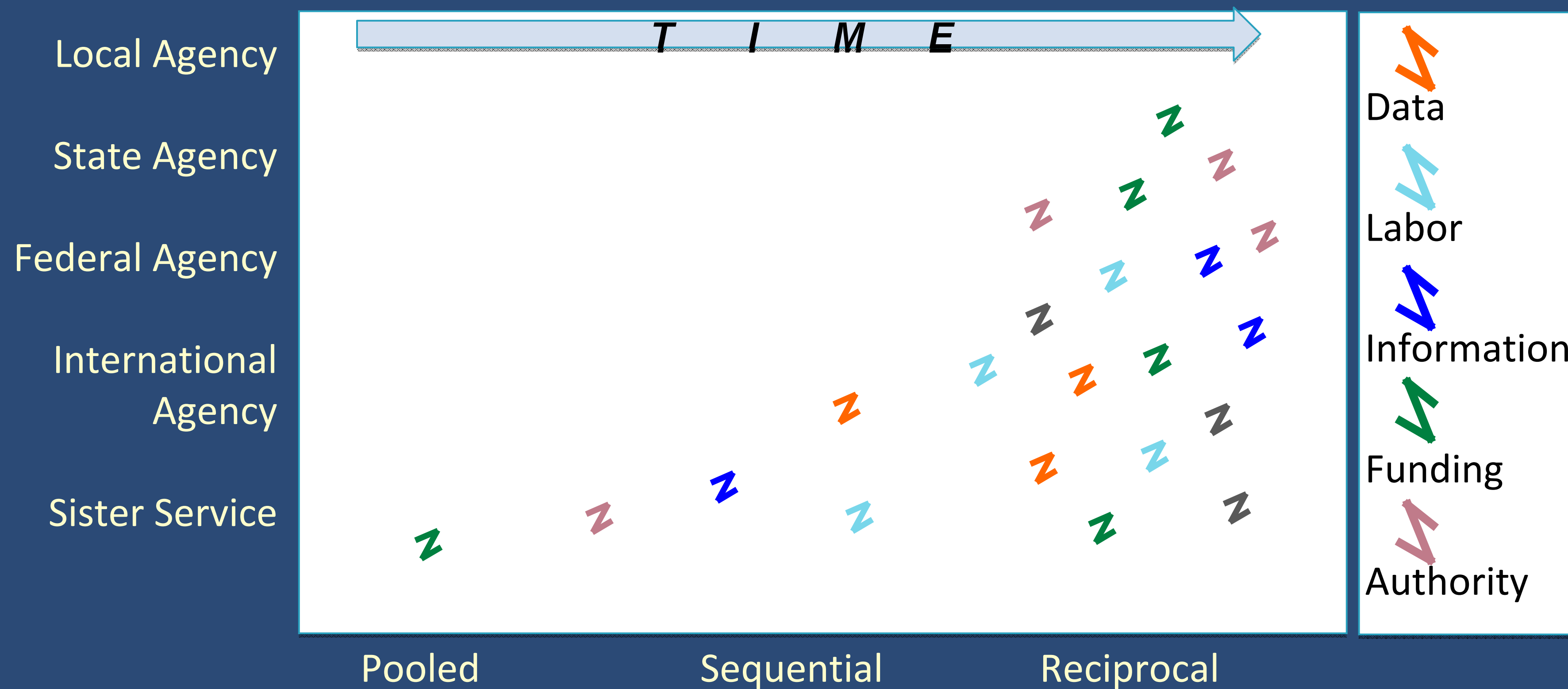
Resource

Financial
Data
Authority
Labor
Information

Agency

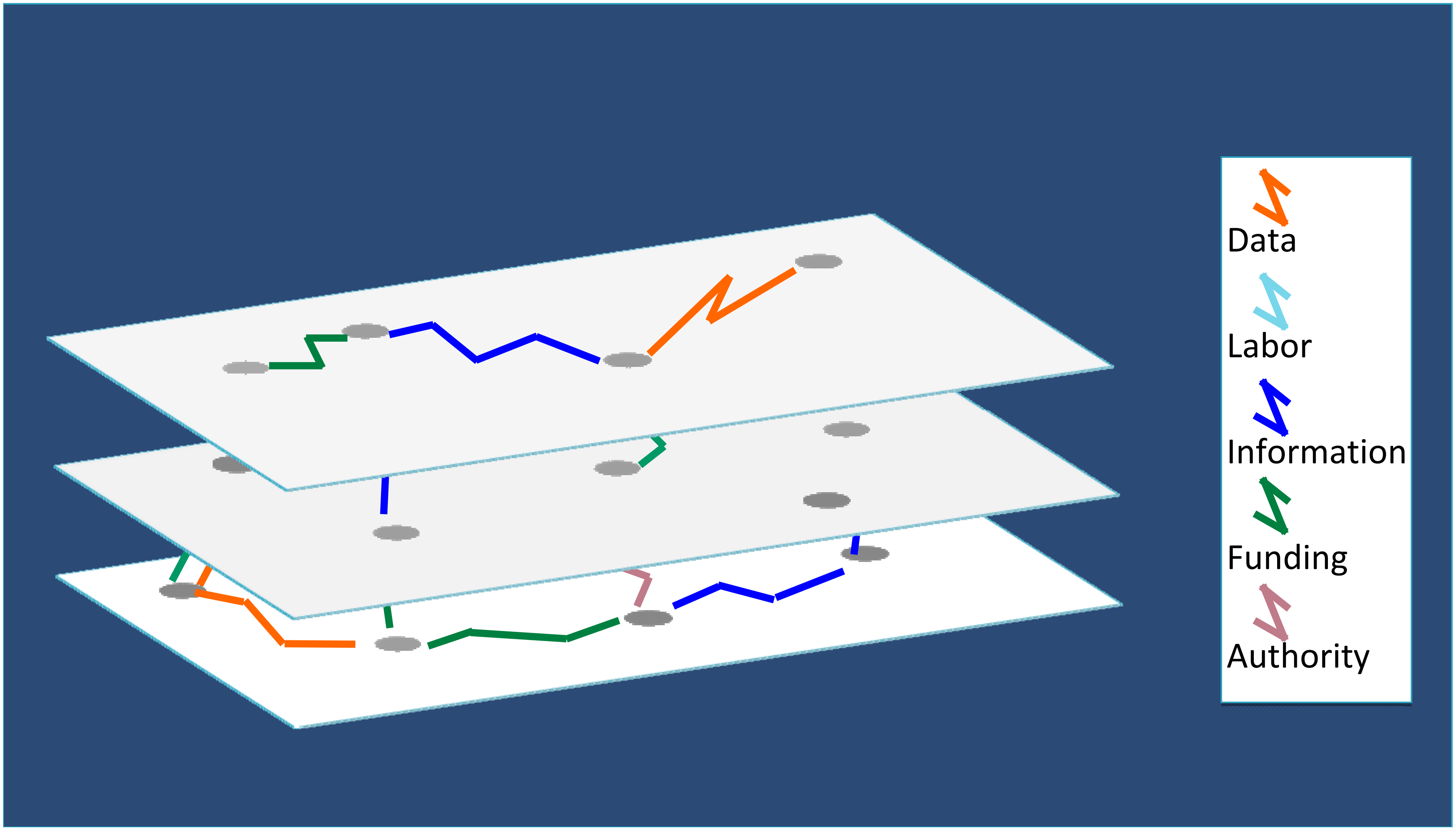
Service
Government
International
Contractor

Pattern Illustrations



Pattern & Binding Illustrations

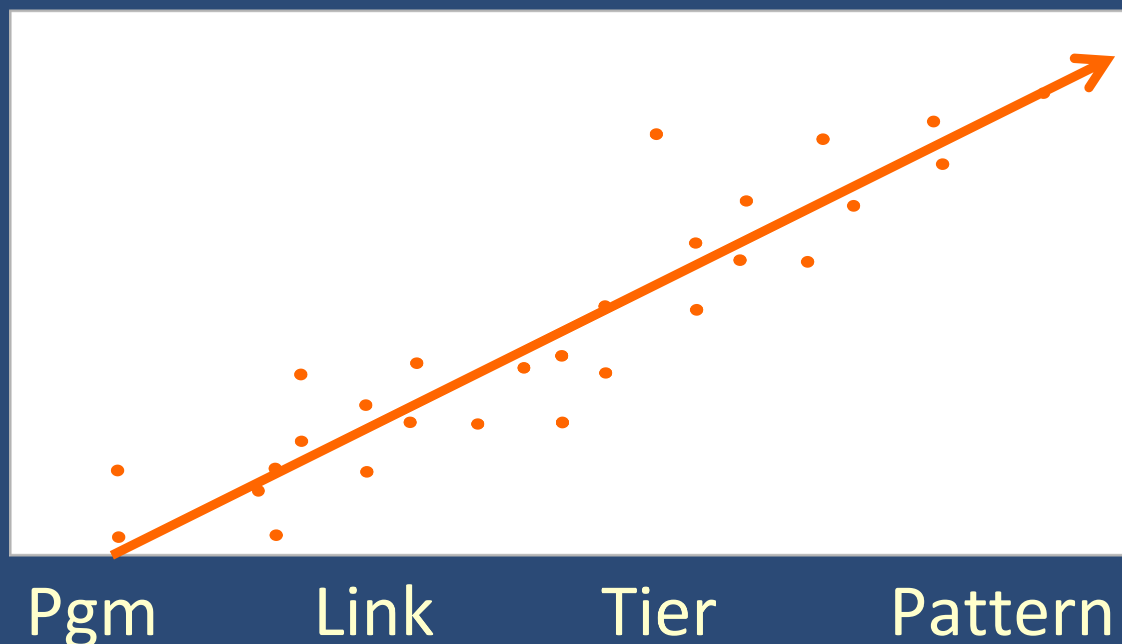
Program, Link, Tier, Pattern Knowledge



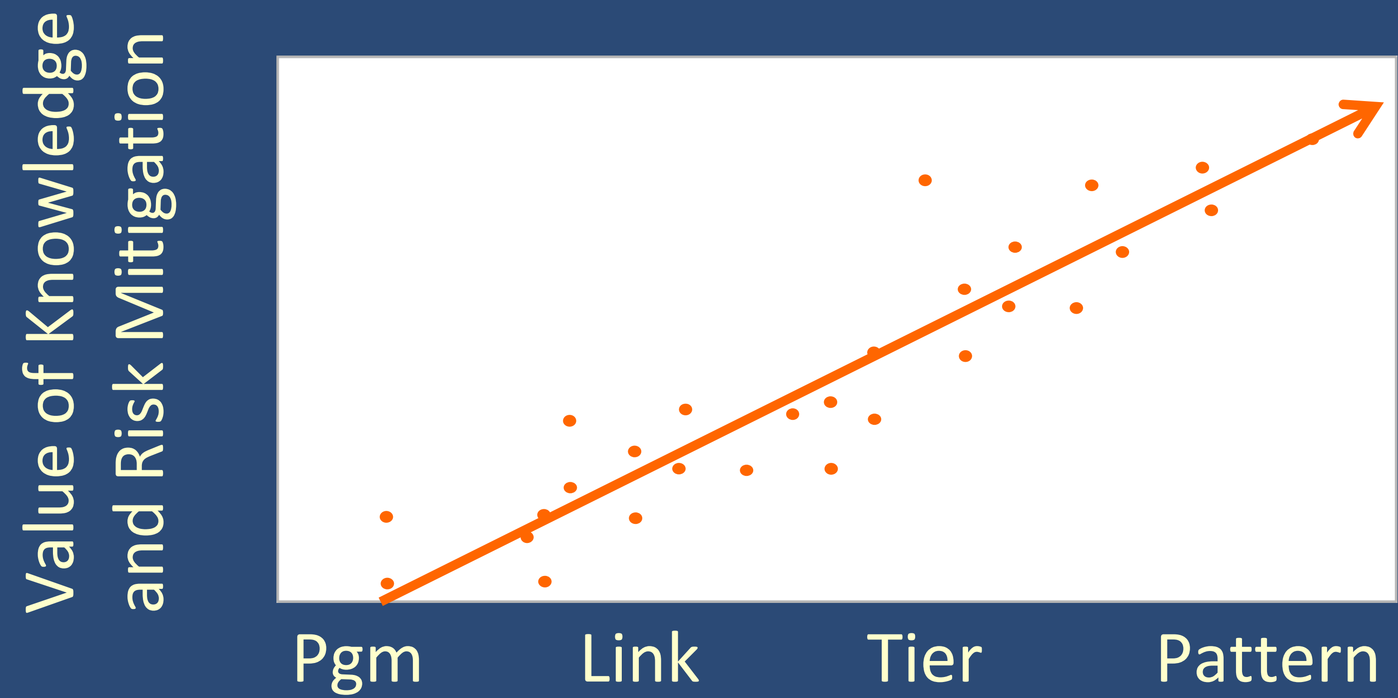
Value Proposition

Knowledge of:

Bandwidth
Congestion
Noise
Redundancy
Instability



Value Proposition



Research Objectives

Applied Research :: 2010

- Map program interdependence to reveal the directionality of influence of cause-effect relationships
- Test the cascading risks that upstream programs exert on downstream programs in light of data and funding exchanges
- Test the extent to which the cost overruns & schedule delays of upstream programs cascade on to interdependent downstream programs
- Employ the findings to make recommendations on potential governance mechanisms that may prove capable of mitigating the risks of interdependencies
- Provide a research code book of acquisition data elements for future research efforts

Data Interdependencies

Growing Interdependencies and Growing Complexity

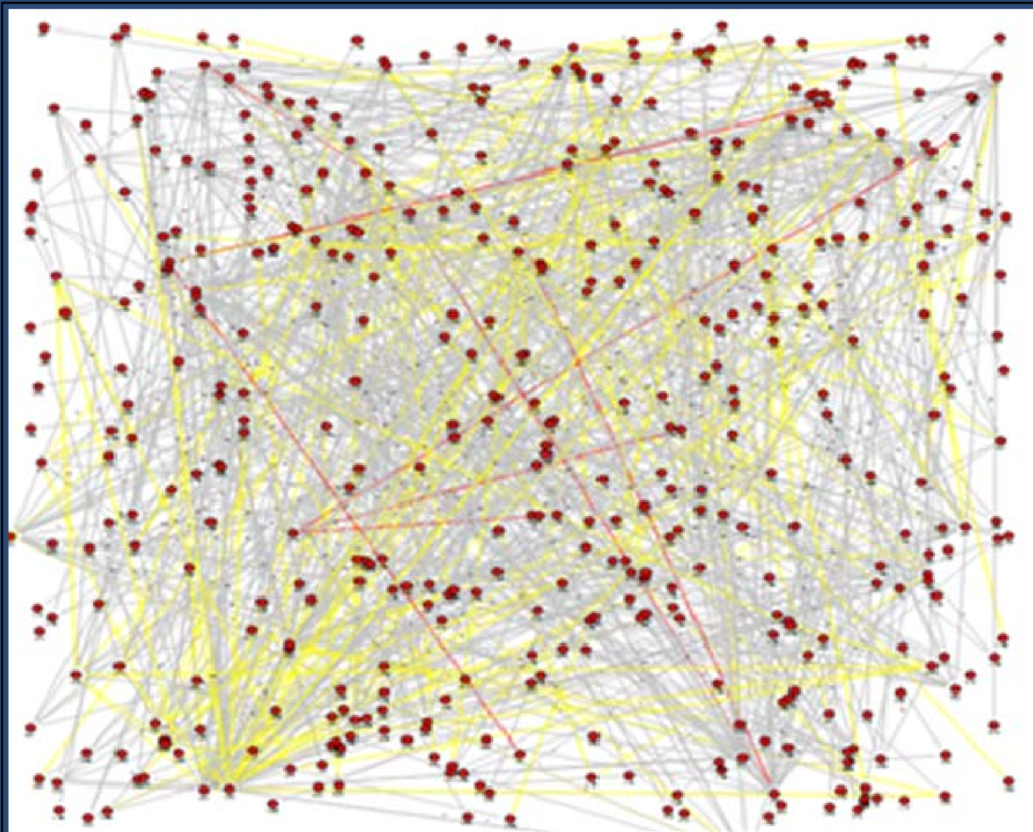
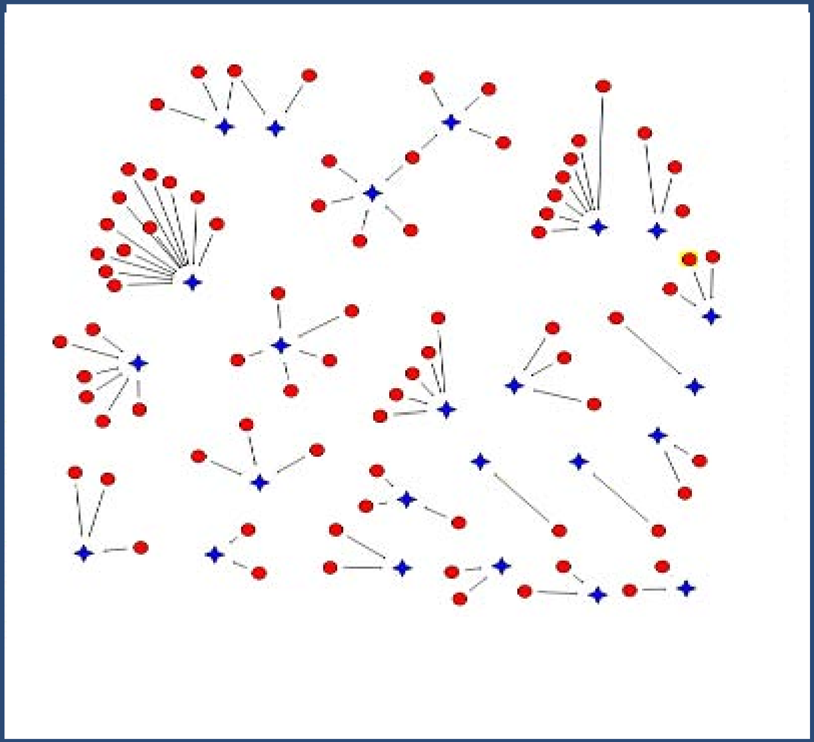


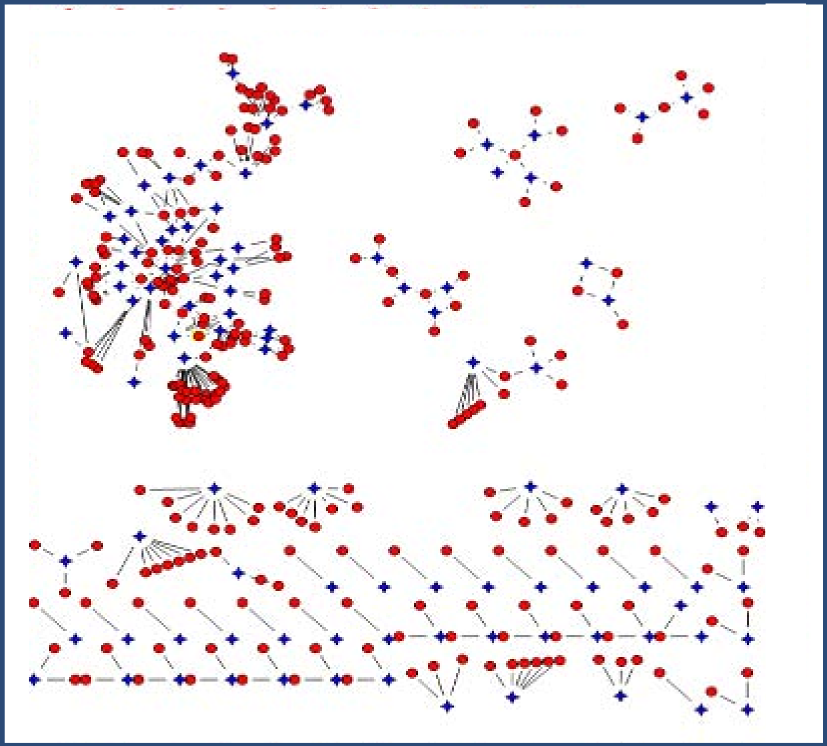
Figure 1: MDAP Data Interdependencies in 2005

Program Element Interdependencies

Growing Interdependencies and Growing Complexity



PE MDAP Relationships 1997



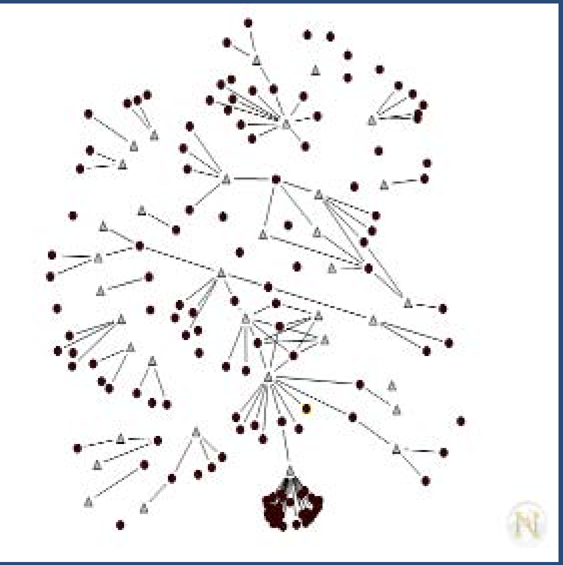
PE MDAP Relationships 2007

Program Element Interdependencies

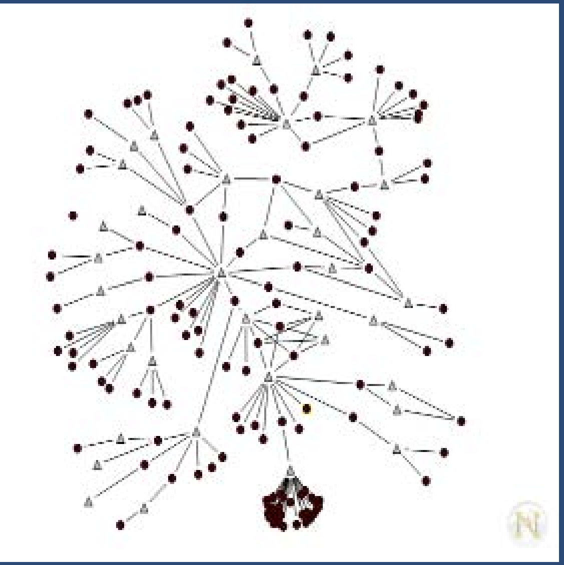
Growing Interdependencies and Growing Complexity

2004

2005



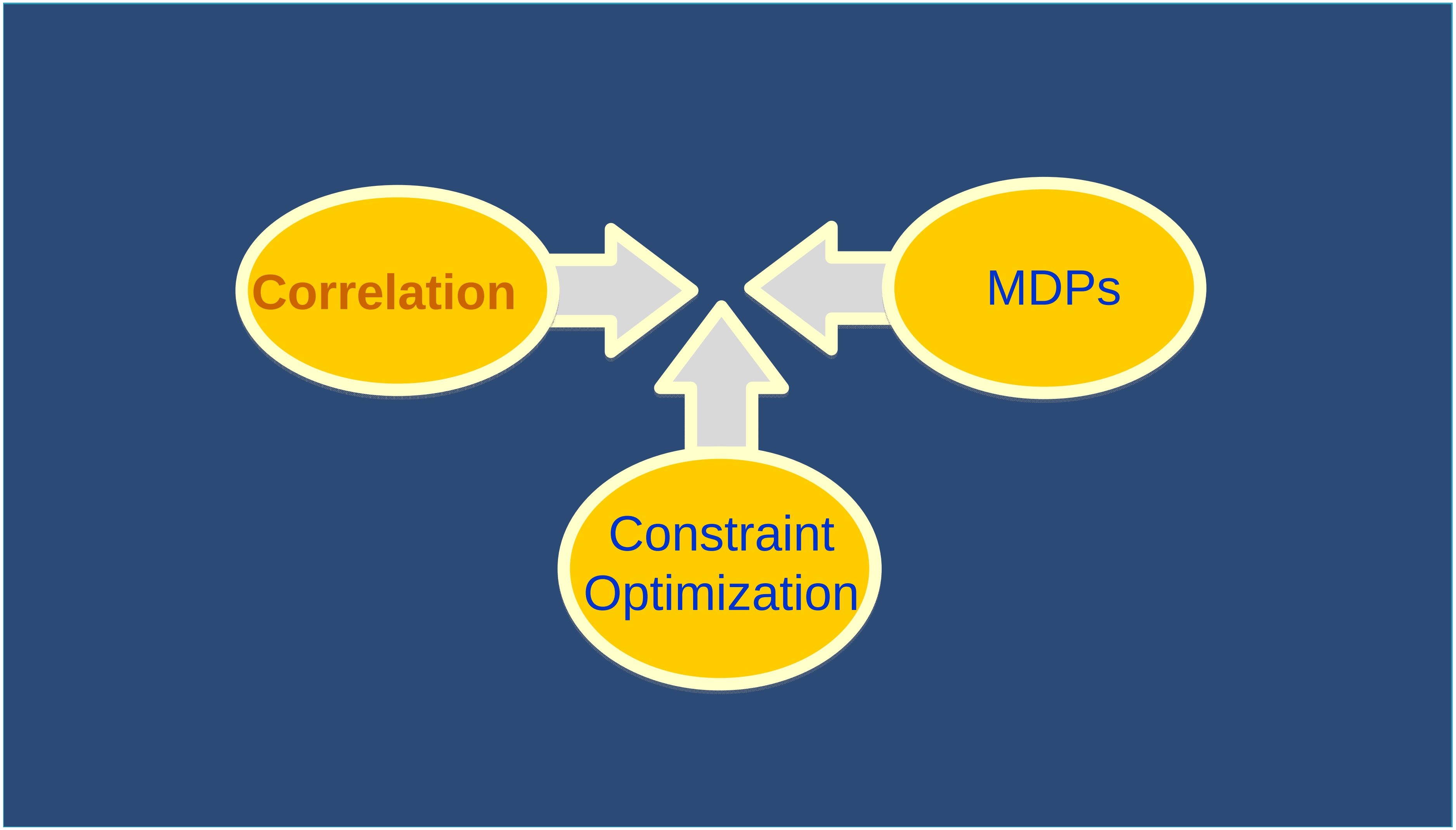
2006



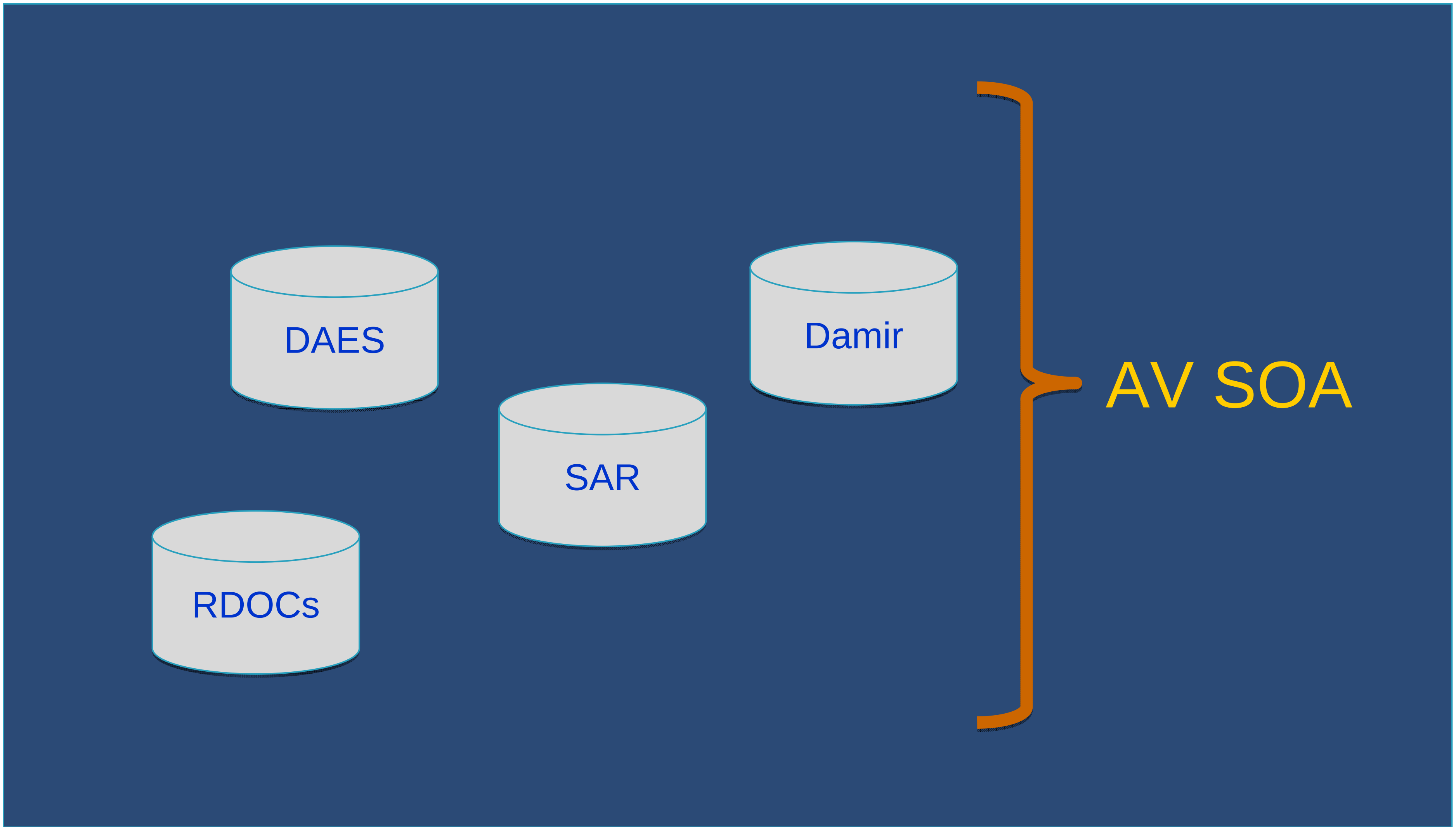
2007

Information Value

Nonlinear and Linear Methods



Datasets



Variables

Data Exchange

Interdependencies

APB Schedule ::
APB Performance Breaches ::
APB RDT&E Breaches ::
PAUC Breaches

Total Cost Variance ::
Engineering Cost Variance ::
Schedule Cost Variance ::
Estimation Cost Variance ::

Percent Cost Growth

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Preliminary Results: Correlation Coefficients

Program Manager's Perception of Data Risk (2005-2007)

Self

Engineering Cost Variance	-.08*
Performance Breaches	.11*
RDT&E Breaches	.13**

Downstream

Total Cost Variance	-.12**
Engineering Cost Variance	-.22**
Estimation Cost Variance	-.11*
Performance Breaches	.13**
RDT&E Breaches	.09*
PAUC Breaches	.12**

Correlation

Correlation Coefficients

Preliminary Results :: Lagged by One Year

Sender APB Performance Breaches ::

Downstream RDT&E Breaches .07*

Sender Total Cost Variance ::

Downstream Schedule Cost Variance .09*

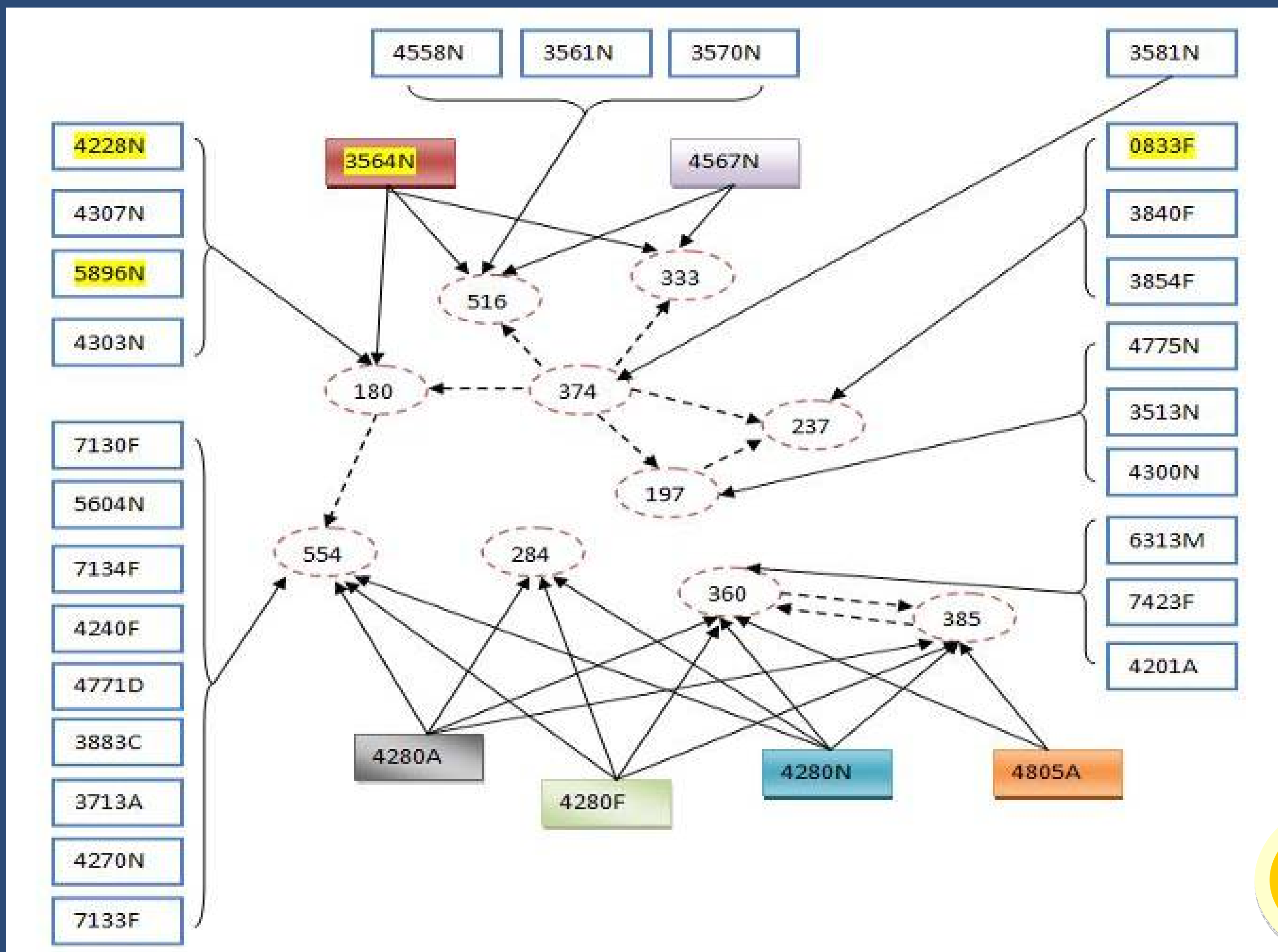
Sender Engineering Cost Variance ::

Downstream Percent Cost Growth .12**

Upstream Influence on Downstream Programs

Correlation

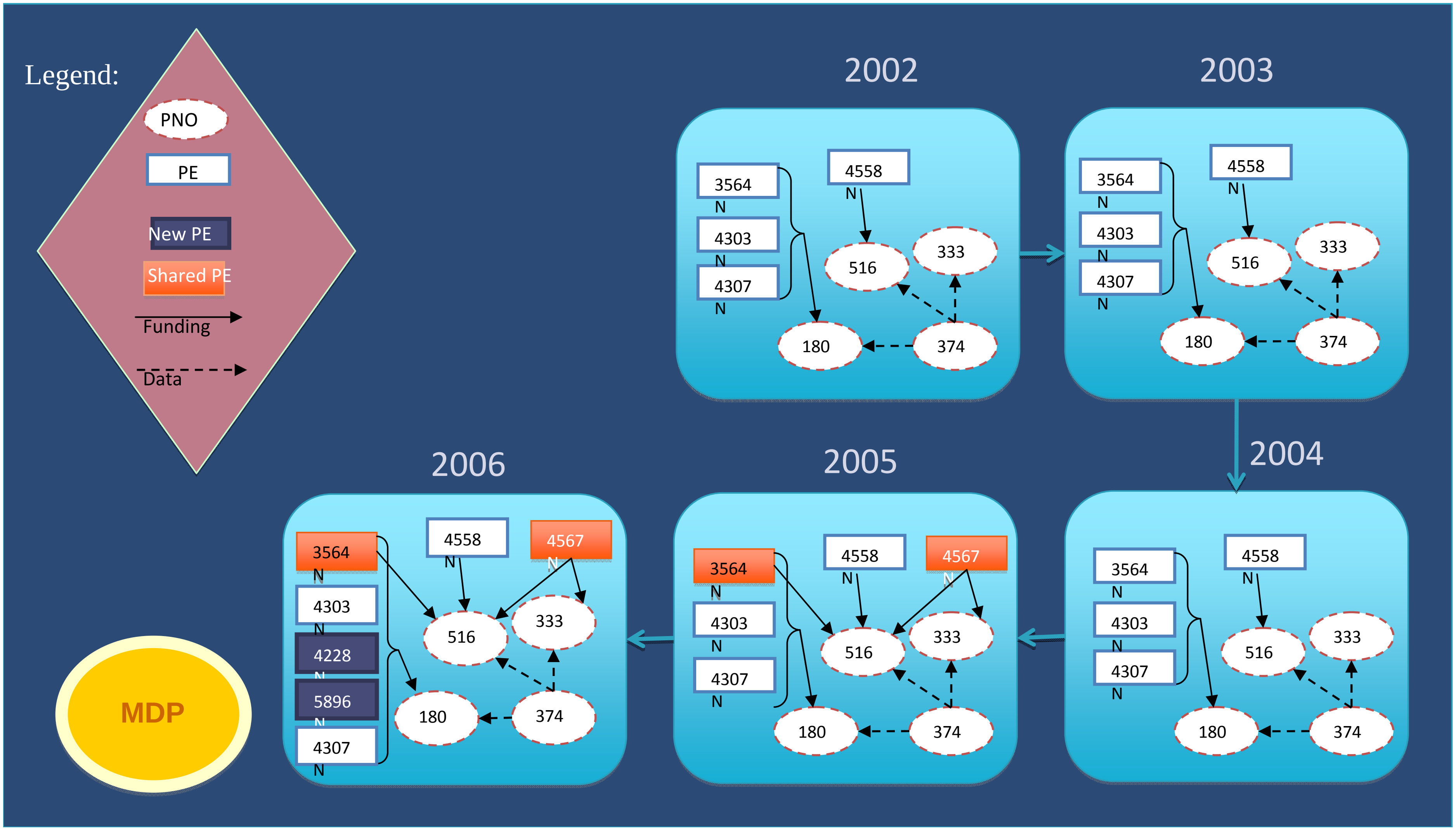
Network of 10 nodes in 2006



MDP

Network Evolution over Time

From the perspective of PNO 180



Markov Decision Processes

R... ty is key.

... nes over time to support

MDP... sequential decision making.

Computing optimal p... gramming will support non-myopic d...

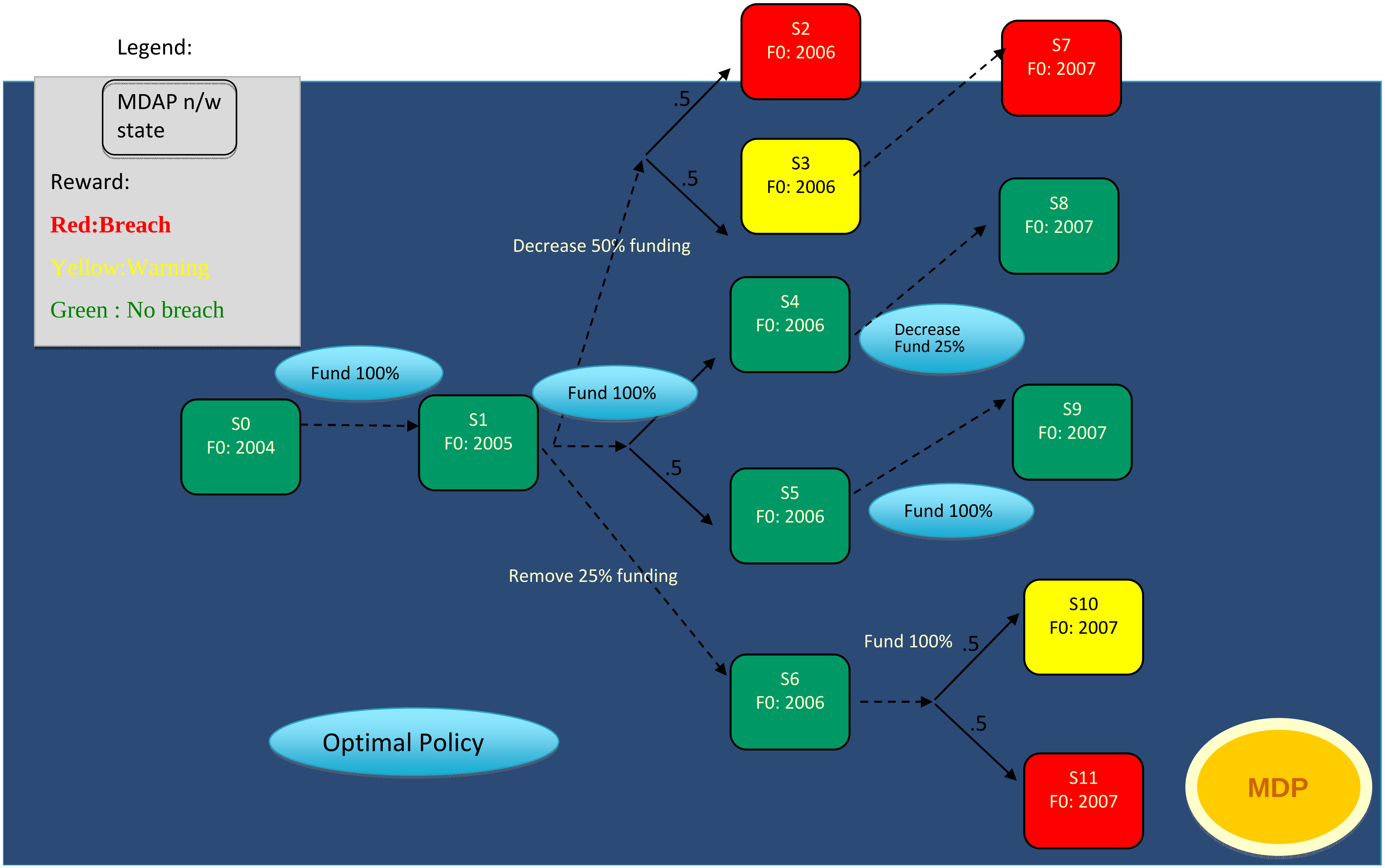
Interested in studying the effects of subtle changes on the overall behavior of the MDAP network !

First order and second interdependencies among MDAPS

And sequential effects!

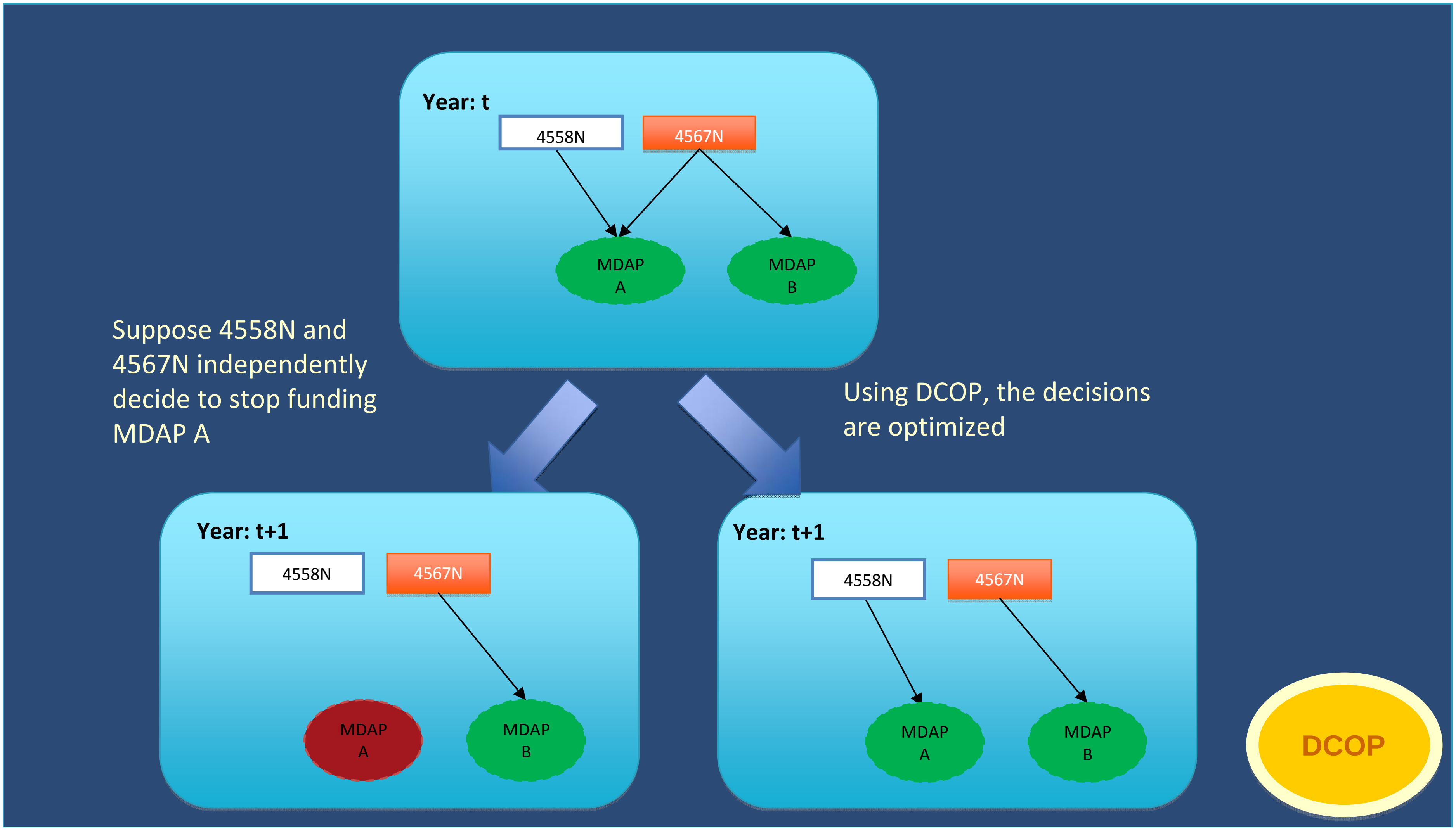
MDP

Sample MDP of a MDAP network



Distributed Constraint Optimization

Study effect of distributed "What if" questions on MDAP n/w



Data Acquisition Road Blocks

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Missing Data in a 10 node network

- PAUC data from 2002 to 2006 is incomplete:
  For e.g. Data for critical node PNO 374 is missing.

- Funding proportion data from 2004-2007 is incomplete:
  PNO 180 only has 2005-2007 data.

- ~ 40% of "PNO spending under PE" data in this set not available.

Next Steps

- Map program interdependence to reveal the directionality of the influence of cause-effect relationships — ✓ *Add 2008 - 2009*
- Test the cascading risks that upstream programs exert on downstream programs in light of data and funding exchanges — ✓ *Test 2005 - 2009*
- Test the extent to which the cost overruns & schedule delays of upstream programs cascade on to interdependent downstream programs — ✓ *Test 2005 - 2009*
- Employ the findings to make recommendations on potential governance mechanisms that may prove capable of mitigating the risks of interdependencies — ✓ *December*
- Provide a research code book of acquisition data elements for future research efforts — ✓ *December*

Back up Slides

Markov Decision Process (MDP) model

MDP Factored State Features:

- F0: Year
- F1: Current PNO ID and % change in its PAUC
- F2: Set of PE(s) funding PNO
- F3: Engineering cost variance
- F4: Schedule cost variance
- F5: Estimation cost variance
- F6: PEs with funding relationships and PAUC % change
- F7: PEs with data relationships and PAUC % change

MDP

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MDP model

Action, Transition, Reward

- Action space: Cross product of diversity features
  - <Total # of PES> X <# of funding services>
  - Other diversity features being studied are level of funding; command levels; # of intl partners; joint requirements.
- Transition Probabilities: Obtained statistically from generalizations of past data from 2002-2007
- Reward Function: Based on Nunn – Mccurdy breach threshold
  - Red: PAUC% >15%;
  - Yellow: 5% -15%
  - Green: PAUC %< 5%

MDP

Reward transition for PNO 180

Distributed Constraint Optimization

Given:

- Variables {x1, x2, …, xn},
- Finite, discrete domains D1, D2, … , Dn,
- For each xi, xj, valued constraint fij: Di x Dj $\rightarrow$ N.

Goal:

- Find complete assignment A that maximizes/minimizes F(A) where, F(A) = S $f_{ij}(d_i,d_j)$, $x_i \leftarrow d_i, x_j \leftarrow d_j$ in A

MDP

Value of Information in Decision Networks

Supporting Joint decision making by multiple Program Managers

Value of Computation

- Captures the value of being able to know "not only additional uncertainties but also additional decisions already made by other team members" before making some other decisions in the team decision situation.

Influence diagram

- Generalization of a Bayesian network
- Structured to accommodate team decision situation where incomplete sharing of information among team members can be represented and solved very efficiently.